GROWTH RATE AND PROPAGATION STUDIES AND PLANT GROWTH REGULATION OF *DRACAENA MARGINATA* LAM.

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ABSTRACT

Research was conducted on Dracaena marginata Lam. with the objectives being to determine the growth rate of established plants and to relate this to discovering effective means of obtaining the maximum yields from stock plants. Research was also conducted on the propagation of cuttings, in the interests of determining what environmental conditions, and chemical treatments result in the maximum rooting and shoot development of these cuttings.

The growth regulators N6 benzyladenine (N6BA), 6-benzylamino-9-(2-tetrahydropyranyl)-9H-purine (PBA), and 2-chloroethanephosphonic acid (ethephon) were effective in increasing the number and percentage of shoots developing on stems treated with these materials, but these shoots elongated more slowly than the controls.

In investigations of different stock plant management schemes, the stock plants which received no cytokinin treatment produced more shoots reaching ten cm in length over an eight month period, when compared to those treated with PBA at 1000 ppm.

Terminal cuttings rooted better under high light intensity (up to 14,000 foot candles), than under low light intensity (up to 450 foot candles). Both terminal and stem cuttings rooted better under intermittent mist, and a greater number of shoots were initiated on stem cuttings under mist. Hardwood cuttings rooted most readily, and shoots developing on both hardwood and semi-hardwood cuttings elongated more rapidly than shoots developing on greenwood cuttings. Vertical orientation of the cuttings was superior to horizontal orientation with regards to both rooting and shoot development.

Indolebutyric acid (IBA) when applied alone to the bottom end of cuttings at the time of propagation, was most effective at 3000 ppm. When the cytokinin PBA was applied at 1000 ppm to the stock plant four days prior to taking cuttings, rooting was greatly inhibited. The most effective treatment with stem cuttings was the application of IBA at 3000 ppm to the bottom end of the cutting and with PBA at 1000 ppm applied to the apical end of the cutting at the time of propagation. Terminal cuttings treated with IBA at 3000 ppm rooted better than untreated cuttings.

The application of N_6BA, PBA, or ethephon to the apical end of both 30 cm and ten cm stem cuttings significantly increased the number and percentage of lateral shoots developing on them. Shoot elongation was reduced on cuttings treated with the higher levels of chemical concentration.

Disease incidence of cuttings by Erwinia carotovora and Fusarium moniliforme may be reduced by curing the cuttings in an open greenhouse with about 10% natural sunlight intensity and temperature ranging between 15.5 and 31°C for four days after cutting, followed by a post-curing dip in Captan at 2.4 grams per liter of water.

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INTRODUCTION

Dracaena marginata Lam. has considerable value as a landscape specimen or house plant, and is a favorite of both home growers, and landscape architects alike.

Efficient means of propagating this plant is important to nurserymen. The growth rate of the stems, and other growth phenomena such as leaf development, affect the amount of propagating material available over a period of time from stock plants. Environmental factors such as light, available moisture, and nutrition affect these growth rate phenomena and may be manipulated by the grower to achieve the most rapid growth of stock plants.

It may be possible to increase the number of lateral buds on cut-back stems of Dracaena marginata stock plants, with the use of growth substances. This would also increase the quantity of propagating material on a stock plant.

The manipulation of such factors as light, intermittent mist, the orientation of the cuttings in the rooting medium, and the age or stage of development of the cutting material may lead to faster rooting and better shoot return on cuttings.

Growth substances may also be of value in stimulating rooting and sprout development on cuttings of this species. This would result in faster production of plants from cuttings, and cuttings of better quality.

Dracaena marginata is affected by a number of serious pathogens. Two of these are Erwinia carotovora, causing bacterial soft rot, and

Fusarium moniliforme. The control of these pathogens would result in a considerable saving of propagating material.

The objective of this research was to provide information regarding these factors to the plant production industry. The objectives of the plant growth studies were to determine the growth rate of Dracaena marginata stock plants, as measured by the growth rate of stems and the rate of leaf production. The objectives of the stock plant management experiments were to determine the number of shoots that would develop on a cut-back stem of a stock plant, and whether the use of growth substances would increase this number, and increase cutting yields from these stock plants. The objectives of the experiments on propagation conditions were to determine what environmental conditions are effective for promoting rooting and bud development on cuttings. Investigations with growth substances were carried out to determine whether certain materials could be used to hasten root development on cuttings. An experiment involving the use of growth substances for promoting shoot development on cuttings was also conducted to determine whether these substances could be used to promote greater shoot development on cuttings, and a faster production of plants from cuttings. The disease control experiments were conducted to discover an effective means of preventing disease in Dracaena marginata cuttings.

REVIEW OF LITERATURE

The Botany of Dracaena marginata

The name 'Dracaena' is Greek for dragon, because of the imagined resemblance of the thickened sap to dragons blood (25). The Dracaenas are members of the Family Liliaceae. About 40 species of Dracaena are known, most of them from the eastern hemisphere. Dracaena marginata (Lam), a native of Madagascar, reaches a height of over 12 feet and produces red-edged leaves to 24 inches in length and up to 0.6 inches in diameter. These plants are tropical, and require warmth, and very well drained soil.

The sap of some dracaenas was used for medicinal purposes in ancient times (25). More recently the sap of some species has been used for varnish. Perhaps the greatest economic value of these plants however, is their ornamental quality. Dracaena marginata, also known as the Madagascar Dragon Tree, and money tree, has become a favorite of both home gardeners, and landscape architects alike.

Growth Rate

Research on growth rate has been undertaken with foliage plants. Ficus elastica cv. Decora (22) produces an average of 36.6 nodes annually, with an average of 3.6 produced monthly in spring and summer, and 2.5 during the fall and winter. The branches increased in weight by 1200 g over a four month period, and the ninth and tenth leaves below the branch tip remained on a branch for an average of 231 days. The formation of nodes by a branch was unaffected by the position of the branch on the tree.

Propagation Conditions

In experiments, using leafless stem cuttings of pea (40, 41) treated with indoleacetic acid, it was demonstrated that light at any wavelength decreased the amount of roots developing on the cuttings. However, cuttings with leaves remaining on them, and not treated with auxin rooted best in white light. Carpenter et al. (6), working with vegetative cuttings of chrysanthemum, geranium, and poinsettia, found that high intensity supplementary lighting applied in the winter, increased root number, length, and fresh weight, over the non-lighted cuttings. Tillburg (34) discovered that shoot tissue of Phaseolus vulgaris, exposed to light for five days, developed a higher level of IAA than etiolated seedlings.

It has been known for sometime that there are important advantages, and some disadvantages to the use of mist in propagating cuttings. Blomme and Hulle (2) found that cuttings of Chamaecyparis pisifera propagated under mist gave a much higher rooting percentage, and rooted much more rapidly than cuttings of the same species propagated under plastic. Herbaceous cuttings of several ornamental species (7) rooted better under mist than out of mist. When supplementary lighting was given, cuttings propagated without mist became dehydrated and many died. Intermittent mist appeared to greatly enhance the rooting percentage, average root length, and survival of herbaceous cuttings of Anthurium andraeanum (18). In tests where leaf temperatures were recorded (20), the leaf temperature of cuttings propagated under mist were 10 to 15°F cooler than those not under mist. Further experimentation (14) with mist revealed that the use

of intermittent rather than constant mist used relatively little water, and temperatures in the rooting area of the medium are higher and more conducive to rooting. Additional research (19, 35), has shown that subjecting leaves to constant soaking or drenching with water will extract nutrients, both organic and inorganic, from them. To offset this effect, adding nutrients to the mist in very low quantities, may replenish those nutrients lost due to the leaching action of the water (46).

Hormonal Regulation of Root Development

Considerable attention has been focused on the use of natural and synthetic growth hormones to stimulate root initiation and development of cuttings. Of these materials, the indole auxins are among the most promising.

Indolebutyric acid (IBA) has been shown to be highly effective in stimulating root development of cuttings from a number of species (1, 9, 10, 12, 23). With *Ilex* and *Juniperus* cuttings (10) 2500 and 5000 ppm are the concentrations which appear most effective. Beck and Sink (1) obtained results indicating that formulations containing certain auxins, usually IBA or NAA (napthaleneacetic acid), were most effective in rooting stem cuttings of poinsettia. McGuire et al. (24) found that foliar applications of 3-indolebutyric acid (IBA) will stimulate root initiation in a number of woody ornamental plants, provided the concentration of the auxin is sufficient. These same researchers (23), using carbon 14 labeled indoleacetic acid (IAA-2-14C), and terminal cuttings of *Ilex crenata*, demonstrated that additional wounding of the cuttings,

and the presence of the apical meristem, had little or no effect on the uptake or movement of the growth regulator.

The mode of action of auxin appears to involve the induction of the synthesis of proteins which may act as enzymes, allowing the extension of cell walls (11).

Hormonal Regulation of Shoot Development

An important aspect of both stock plant management, and the propagation of cuttings, is the development of lateral branches from these materials. This phenomenon of shoot development is controlled in part by hormonal regulation, and may therefore be manipulated to a degree with the application of specific growth substances.

Sachs and Thimann (29) demonstrated with pea plants, that auxin produced by actively growing shoots inhibited the initiation of other lateral buds and released them from the auxin induced apical dominance. They also found that buds released from apical dominance by kinetin did not elongate as rapidly as did actively growing buds on untreated plants.

Further research with cytokinins (4, 5, 17, 27, 33, 44, 45) indicates that these growth substances may be of considerable value in stimulating lateral shoot development of economically important plants. With Cordyline terminalis, both N_6 benzyladenine (N_6BA), and 6-benzylamino-9-(2-tetrahydropyranyl)-9H-purine (PBA) were found to be highly effective in promoting shoot initiation and development (33). Applications of N_6BA to actively growing, non-fruiting shoots of apple (44) were effective in stimulating lateral bud growth on these shoots. The cytokinins N(purin-6-yl) phenyl-glycine (NPG), and PBA were also found

to release axillary buds of apple shoots from apical dominance (45). Boswell and Storey (4) have demonstrated that PBA, when applied to seedlings of Macadamia tetraphylla L. will induce sprouting of axillary buds. The concentrations that were most effective were 500 and 1000 ppm, when applied four times at weekly intervals. The cytokinin treatments however reduced the growth of the terminal shoot. Research by Parups (35) indicated that the development of bottom breaks and growth of lower buds of greenhouse roses may be induced by the application of N_6BA, and adenine as a lanolin paste.

Carpenter et al. (8) found that PBA at 200 and 1000 ppm caused the development of between 90 and 100% of the lateral branches of poinsettia cuttings. Ethephon (2-chloroethanephosphonic acid) at 500 ppm stimulated lateral bud development significantly above the control but to a much lesser degree than the two cytokinins. The most effective treatment in this experiment appeared to be PBA at 200 ppm, with 100% of the lateral buds developing.

The mixture of C_6-C_{12} Methyl esters of fatty acids with ethephon (31) were found to increase the number of branches per shoot, and the number of shoots per plant, with azalea, when utilized as chemical pinching agents. Leaf cuttings of Sedum rubrotinctum (3) responded well to treatments of ethephon, N_6BA, and ethylhydrogen 1-propylphosphonate (EHPP) by producing more shoots than control plants. Cuttings treated with ethephon at 500, 1000, or 2500 ppm produced more shoots than with any concentration of N_6BA or EHPP tested. The most effective concentration of ethephon was 1000 ppm. Two cytokinins, PBA and N_6BA, were found to increase the branching of poinsettia stock

plants, resulting higher cutting yields (5). Cuttings taken from branches induced by the cytokinin treatments were slow to root. Sachs and Thimann (29) demonstrated that kinetin could counteract the inhibition exerted on lateral buds of 'Alaska' pea by an intact apex. Wickson and Thimann (42) after considerable research, concluded that kinetin at 4 to 5 ppm would remove the bud-inhibiting effect of from .3 to 5 ppm of IAA. These researchers (43) also stated that the phenomenon of apical dominance depends upon the interaction of auxin and a kinetin-like substance in the plant. Overbeek stated (26) that auxin produced by the terminal is responsible for the inhibition of lateral bud development, and when this terminal is removed, the upper most lateral buds on the stem begin developing, and in a very short time produce sufficient auxin to prevent the development of other buds.

More recent information about cytokinins (11, 28, 38) suggests that their mode of action may be an effect upon protein synthesis. Cytokinins may also play a role in nucleic acid metabolism, as they have been incorporated into at least two types of specific transfer RNA: serine T-RNA and tyrosine T-RNA (28). Cytokinins may therefore be partly responsible for the proper transcription of the genetic code. Although their exact mode or modes of action are not yet known, it is generally accepted that cytokinins are inducers of cell division, and are involved in cell regulation, and differentiation (38).

Ethylene is known to accelerate RNA synthesis at abscission zones, regulating abscission (28). Ethylene is also involved in the stimulation of cell division (11). This material probably plays a role in the transcription and translation of the genetic code, and

may be incorporated into RNA as are some other plant hormones (38). One hypothesis regarding the mode of action of ethylene states that ethylene alters the transport and metabolism of auxin (38). Another suggests that ethylene stimulates important enzyme systems associated with cell membranes.

Disease Control

A number of pathogens are serious inciters of diseases of Dracaena marginata. Perhaps the most serious is Erwinia carotovora, the causal agent of bacterial soft rot.

Wounds appear to be the greatest avenue of infection for this organism (15, 36, 37). These wounds may be brought about by such causes as harvest bruises, freezing, and insect damage (37), or by cutting or trimming the plant material, as a part of post-harvest handling (36). Contaminated water in washing basins, resulting from washing infected material, is also a means of transmitting the pathogen to wounded, but healthy plant material (36). Johnson (15) found that decay of bell pepper fruit stalks by Erwinia carotovora was increased with increasing stalk moisture content. High relative humidity, and moderate to high temperature also favor the growth of Erwinia (16, 36). Kaperstin (16) noted that Erwinia will develop at temperatures ranging from 5 to 26°C, and 96 to 100% relative humidity. The bacteria of the genus Erwinia can live for a considerable period of time in the soil (36).

With susceptible plant material, the most important control measures have to do with the handling of the material at and after harvest (36). Bruising or wounding plant parts should be avoided,

and wounded surfaces should be allowed to form a cork layer (37). Johnson (15) showed that soft rot in bell pepper could be prevented by dipping the green fruits in a 150 to 300 ppm chlorine solution. Kaperstin (16) demonstrated that disinfecting storehouses with 5% $CuSO_4$, and ventilation, and treatment of the seed pieces with thiram, cuprosan, and phosphate fertilizer were effective measures of controlling bacterial soft rot of potato.

Wehlburg and Martinez (39) noted that Fusarium moniliforme incites a disease of Dracaena marginata by colonizing at the leaf base, slowing growth and distorting the tip. This problem may be controlled very effectively with weekly applications of Dithane M-45, and Daconil 2787.

The reference files of the Plant Disease Clinic at the University of Hawaii indicate that in addition to Erwinia carotovora, and Fusarium moniliforme, a number of pathogens including Collectotrichum, Pythium, Xanthomonas, and Stemphyllium incite diseases of Dracaena.

MATERIALS AND METHODS

Experimental Conditions

The majority of these experiments were conducted under one of the environmental conditions described in the following paragraphs. Each of these areas mentioned are located on the campus of the University of Hawaii at Manoa.

A. Magoon Horticulture Greenhouse

This greenhouse is an entirely enclosed structure composed of glass and aluminum, with raised wood benches 75 cm above a gravel floor. The temperature in this house ranged, throughout the duration of these experiments, from 15°C to 42.2°C. The average low night temperature was 20.9°C, and the average daily high temperature was 35.5°C. The relative humidity ranged between a low of 20% in the day, and a high of 100% in the night, with a daily average of 35.4% and a nightly average of 95.0%. The plants in this greenhouse were exposed to 50% natural sunlight intensity, throughout the entire daylength. The maximum light intensity reading inside the greenhouse was 7000 foot candles.

B. Mid-Pacific Horticulture Propagation Facility

This facility is a small area that consists of mist benches, a greenhouse, a saranhouse, and an open outdoor area for growing and propagating plants. The general environmental conditions such as relative humidity and temperature, are similar for all of these facilities. The temperature ranged, throughout the duration of these

experiments, from a maximum of 31.1°C in the day to a minimum of 15.6°C at night, with an average daily high temperature of 28.4°C, and an average low night temperature of 21.6°C. The relative humidity ranged between a high of 100% in the night to a low of 26% in the day, with the average daily low being 50.5%, and the average high at night being 96.3%. The average monthly rainfall was 17.4 cm, with a minimum of 6.3 cm in the month of June, and a maximum of 42.8 cm occurring in January.

1. Mid-Pacific Horticulture Greenhouse. This greenhouse is a fiberglass structure with a wire screen front and sides, and a corrugated fiberglass roof. The raised benches are 65 cm above the ground, and are composed of heavy gauge wire screening. This greenhouse allows approximately 10% of the natural sunlight intensity to penetrate, with a maximum light intensity of about 1400 foot candles. The greenhouse exterior is exposed to full sunlight throughout the day. The temperature and relative humidity are described under the general heading of the Mid-Pacific propagation facility.

2. Mid-Pacific Saranhouse. This saranhouse is enclosed entirely with a saran screening. The saran allows approximately 45% of the natural sunlight to pass through. Temperature, relative humidity and rainfall are described under the general heading of the Mid-Pacific propagation facility. In addition to natural rainfall, plants in this saranhouse were watered daily.

3. Mid-Pacific Mist Benches. These mist benches are outdoor systems, with intermittent mist operating for five seconds every minute. Some of the benches are exposed to 100% natural sunlight

throughout the entire day, while others are under 100% natural shade. The highest light intensity observed at the exposed benches was 14,000 foot candles. The maximum foot candle reading for the shaded benches was 450. The temperature and rainfall of these benches are described under the heading of the Mid-Pacific propagation facility.

The humidity and temperature data were recorded on a hygrothermograph, and the monthly rainfall was recorded by a rainfall gauge.

Plant Growth Investigations

Specimens used for these experiments were fully mature plants of Dracaena marginata, ranging from approximately 10 to 20 feet in height, with many branches per plant. They were located on the campus of the University of Hawaii at Manoa, and were exposed to similar conditions of relative humidity and temperature, but varied somewhat in their exposure to light. Some were exposed to complete natural sunlight during the day, receiving a maximum of 14,000 foot candles. Others received 100% natural sunlight for one-half of each day, and complete natural shade for the other. Complete natural shade represents a maximum of 450 foot candles. These plants were watered twice weekly. They received no fertilizer except a complete fertilizer was applied to the ground cover surrounding these plants once every six months. All of these plants were equally healthy and vigorous. The conditions of temperature, humidity and rainfall were similar to that described under the heading of the Mid-Pacific propagation facility.

Healthy terminal branches were tagged, and a mark was inscribed on the stem at a point below the zone of stem elongation, with an insoluble

crayon pencil. The newest unfurled leaf of the terminal was marked with a non-toxic spray paint. Ten plants were utilized for the experiment, with two branches per plant being tagged. The age, and vigor of the terminals varied considerably, with a representative amount of each type being studied. These terminals ranged from ones with slow growing narrow stems and extremely short internodes, to rapidly growing watersprouts. The majority of the terminals were on stems averaging two cm in diameter with a moderate growth rate.

Data were taken on the increase in length of the stem between the inscription, and the center of the bulge produced by the overlapping swollen leaf bases, in cm per month. The number of nodes produced per stem per month was also determined by counting the number of nodes between the inscription and the center of the bulge produced by the overlapping swollen leaf bases. The rate of leaf production per stem per month was studied by counting the number of unfurled leaves between the marked leaf, and the furled cluster at the shoot apex (Fig. 1).

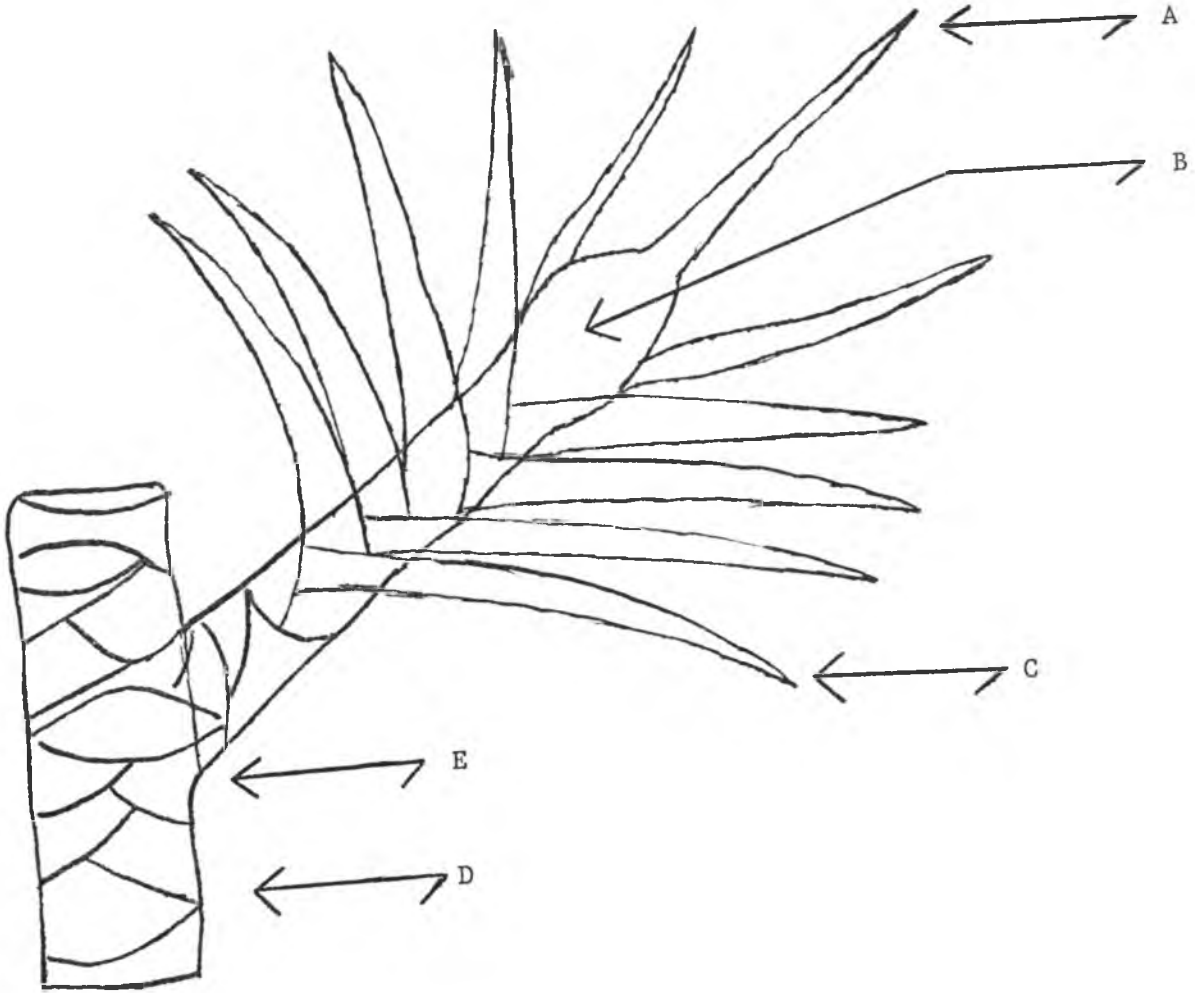
Another two terminal branches on each of the ten specimen plants, were utilized to determine the length of time that a leaf will remain on the terminal after it unfurls. Newly unfurled leaves of these stems were marked with a non-toxic spray paint, and the date of marking and abscission of the leaf were both recorded.

Similar investigations were carried out on well rooted 30 cm cuttings in 15 cm plastic pots containing a soil mix of 50% soil and 50% uncured wood shavings. Ten plants were utilized, each with only a single terminal stem, for the study of stem growth, node production,

Figure 1. A terminal branch of Dracaena marginata indicating parts of the terminal with terms utilized in this research.

A) Furled cluster of leaves
B) Bulge produced by overlapping swollen leaf bases
C) Unfurled leaves
D) Parent stem
E) Attachment of shoot to parent stem

Data taken on length of developing shoots on cuttings or stock plants were on the length of the shoot between the attachment to the parent stem and the tip of the furled cluster of leaves.


A
B
C
D
E

and leaf production. A separate ten plants were used for the leaf retention investigation. The individual plants were all of the same age, and stage of development, and were placed on benches, outdoors, at the Mid-Pacific Horticulture Propagation Facility, and given 70% shade with a saran screening. The environmental conditions are discussed under the heading of the Mid-Pacific Horticulture propagation facility. Aside from natural rainfall, these plants were watered once daily. They were fertilized at three months after the beginning of the experiment with both Osmocote 14-14-14, a slow release fertilizer, and a granular 15-15-15 fertilizer. The 15-15-15 was applied to correct a nitrogen and phosphate deficiency, which developed at about the third month after the beginning of the experiment.

Stock Plant Management

In the first series of experiments, two stems from each of ten fully mature specimens of Dracaena marginata, ranging in size from 10 to 20 feet in height, with many branches, were cut back below the terminal whorl of leaves. Data were taken monthly on the number of lateral shoots produced by each of these stems, and on the growth rate of these shoots in cm (Fig. 1). Data were also taken on the time required for a normal-sized leaf to develop on the new shoots. The date of the appearance of the first identifiable leaf, and the first normal sized leaf were recorded for each cut-back stem.

A second series of experiments involved investigating the effects of three growth regulators on stimulating shoot initiation and development of cut-back stems of mature stock plants. The specimens used for these experiments were the same established plants utilized

for the growth rate experiments. Three chemicals were investigated, N_6 benzyladenine (N_6BA), 6-benzylamino-9-(2-tetrahydropyranyl)-9H-purine (PBA), and 2-chloroethanephosphonic acid (ethephon), at five concentrations, 1000, 500, 250, 100, and 0 ppm. Four cut-back stems were utilized for each treatment. These materials were applied as an aqueous spray directed at the cut-back surface and uppermost several cm of the cut-back stems. The stems themselves varied considerably in diameter, position on the plant, and on exposure to light and wind velocity. The stems were distributed as equally as possible among the different treatments. A mark was inscribed on the cut-back stem well below the zone of elongation, with an insoluble crayon-pencil. Data were taken on the increase in the length of the cut-back stems in cm per month, on the number of shoots developing on each stem, and on the increase in the length of these new shoots in cm per month (Fig. 1). Data for this experiment were analyzed as a 3X5 factorial analysis of variance (32).

In an experiment designed to ascertain which of a number of stock plant management practices would result in the most efficient production of propagating material, five stock plant management schemes were established. One method involved cutting back the main branches, and allowing lateral shoots to develop from these, which were in turn removed after the portion of these shoots between the main stem and the terminal leaves reached ten cm. Another method involved the same procedures as the above method, except that the main stem was cut back flush below the lowest shoot attaining a length of ten cm. If the shoots developing above the lowest shoot at ten cm were shorter than

ten cm, the stem was not cut back until these shoots reached ten cm also. In another two treatments both of the ones previously described were repeated, except that the cut-back stems were treated with an aqueous spray of PBA at 1000 ppm. The PBA was again applied to these plants following the removal of shoots. The fifth scheme investigated involved allowing several shoots to develop from the cut-back stem. These shoots, instead of being removed, were cut back and new shoots were allowed to develop from them. PBA at 1000 ppm was applied to the cut-back stems to stimulate greater shoot production. The second set of lateral shoots were removed when they reached ten cm as in the other experiments. Two stock plants were used for each of the five treatments, and data were taken on the number of shoots removed after reaching ten cm, over an eight month period.

The stock plants utilized were well established plants in one gallon plastic containers. They were each cut back to a stem length of 30 cm at the beginning of the experiment. These stock plants were maintained in the Mid-Pacific saranhouse, and were watered daily. No fertilizer was applied during the course of the experiment.

Vegetative Propagation

With all propagation experiments, immediately upon being prepared, the cuttings were treated with IBA at 3000 ppm, except where the effects of hormone treatments on root development were being studied.

The effects of light intensity, humidity, the orientation of the cuttings, and the maturity of the cutting material were each studied separately. With each treatment of a particular experiment, ten 30 cm and ten 10 cm cuttings were utilized. With the light and humidity

experiments, terminal cuttings with the stem portion below the terminal whorl of leaves measuring ten cm were used instead of ten cm stem cuttings. In studying the effects of the stage of maturity, ten cm terminal, and ten cm stem cuttings were both used. The effects of the orientation of the cuttings were tested with only ten cm stem cuttings. The 30 cm stem cuttings were used in all experiments.

Except when studying the effects of maturity on rooting and sprout development, the cuttings utilized within an experiment varied markedly from one another, with regards to maturity, and were distributed as equally as possible among the different treatments. All cuttings utilized for these experiments were propagated in sterile galvanized seedling flats containing 100% medium (no. 2) grade vermiculite. The seedling flats were sterilized by soaking them in a 10% solution of chlorox.

In studying the effects of light intensity on rooting and shoot development, two light regimes were utilized, one with complete natural sunlight, and the other with complete natural shade. One treatment was placed on the Mid-Pacific mist bench, and the other placed in the Magoon Horticulture greenhouse with no mist.

The effects of orientation of the cuttings on rooting and lateral bud development was studied by placing one treatment horizontally in vermiculite, with the lower one-half of the cutting contained within the medium. Cuttings of the other treatments were placed vertically in the vermiculite. Both treatments were exposed to the Magoon Horticulture greenhouse conditions.

Three stages of maturity were recognized in an experiment studying the effects of this factor on rooting and sprout development. Greenwood cuttings were very succulent, and included cuttings taken from material immediately below the stem terminal, as well as vigorously growing watersprouts. Semi-hardwood cuttings represented somewhat lignified material taken from stems that have a moderately heavy epidermis. Hardwood cuttings are heavily lignified, and include sections of very large branches taken from older portions of the plant. These cuttings were often very large in diameter, and had a considerable amount of bark present. All cuttings were watered as necessary, except for those placed under mist.

Data were taken on a monthly basis, over a three month period, on rooting, and lateral shoot development. The rooting was measured in terms of stages of rooting, and root indexes were calculated for each treatment. The five levels of root development measured were: dead or rotted (stage 1), alive with no roots (stage 2), a small root mass about seven cm in diameter (stage 3), a medium sized root mass about ten cm in diameter (stage 4), and a large root mass about 13 cm in diameter (stage 5). Shoot development was measured by taking data on the number of shoots that developed on each cutting, and on the monthly increase in the length of these shoots in centimeters (Fig. 1). With shoot development, data for each of these experiments were analyzed as a t-test. With the effects of the maturity of the cuttings on shoot development of 30 cm cuttings, data were analyzed as a one-way classification analysis of variance (32).

The effects of plant growth regulators on root development were studied in a series of experiments. All of these experiments were conducted in the Magoon Horticulture greenhouse, and the cuttings were watered as necessary to the point of saturation of the medium.

The first experiment involved the effects of IBA on root initiation and development of 30 cm stem pieces. The five levels of concentration of IBA used were 4000, 3000, 2000, 1000, and 0 ppm. The IBA was applied as an aqueous spray with the IBA dissolved in 30% ethanol. The applications were made immediately after the cuttings had been prepared, and the solution was allowed to dry on the cutting before it was placed in the medium. Data were taken on a monthly basis over a three month period on root development. The stages utilized to measure this development were: alive with no roots (stage 1), root initiation to a small root mass (stage 2), a small root mass about seven cm in diameter (stage 3), a medium sized root mass about ten cm in diameter (stage 4), and a large root mass about 13 cm in diameter (stage 5). Root indexes were calculated.

In investigating the effects of IBA on root development of ten cm terminal cuttings, two treatments were used. One treatment received IBA at 3000 ppm, applied at the time of propagation, the other was an untreated control. This experiment was conducted under mist at the Mid-Pacific mist bench in full sunlight.

In a second series of experiments, measuring the effects of the hormones on rooting, 30 cm and ten cm cuttings were used. These cuttings were placed in the same greenhouse, and exposed to the same environmental conditions, and management practices as those in the

first series of experiments. There were six treatments in the experiment, with ten 30 cm, and ten 10 cm cuttings tested per treatment. The six treatments were as follows:

1. Control that received no treatment.
2. IBA at 3000 ppm applied to the cuttings at the time of propagation.
3. IBA at 3000 ppm applied to the cuttings, with PBA applied at 1000 ppm to the stock plant four days prior to taking the cuttings.
4. PBA at 1000 ppm applied to the stock plant four days prior to taking the cuttings.
5. PBA applied at 1000 ppm to the upper portion of the cuttings at the time of propagation.
6. PBA applied at 1000 ppm to the upper portion, with IBA at 3000 ppm applied to the lower portion of the cutting at the time of propagation.

Data were taken monthly on the stage of root development. The stages of rooting used for this second series of experiments, and for the investigation of the effects of IBA on the terminal cuttings, are the same stages used for the first series of experiments regarding the effects of IBA on root development. Root indexes were calculated.

An experiment designed to examine the effects of growth regulators on lateral shoot initiation and development was conducted using fully rooted 30 cm and ten cm stem cuttings. The cuttings were rooted in 100% vermiculite, and were maintained under the Magoon Horticulture greenhouse condition. The cuttings, once rooted, were maintained in the vermiculite media. The growth regulators investigated were N_6BA, PBA, and ethephon, and each was applied at five concentrations 1000, 500, 250, 100, and 0 ppm, making a total of 15 treatments. Ten cuttings of each size were allocated to all treatments. These chemicals were

applied as an aqueous spray to the upper portion of the stem, once the cuttings were fully rooted. Initially the cuttings were about 37 cm long, and immediately prior to treatment were cut back to 30 cm, so as to remove any shoots that were already developing on the stem, and also to provide a newly cut surface for better absorption of the chemicals.

A slow release fertilizer, Osmocote 14-14-14, was applied one month after the treatment of the cuttings, to supply adequate nutrition to the cuttings growing in the artificial media. Data were collected monthly, over a three month period, on the number of shoots initiated per cutting, the number of these shoots developing, and the increase in the length of these shoots in cm (Fig. 1). Data were analyzed as a 3X5 factorial analysis of variance (32).

Disease Control

Ten 30 cm and ten 10 cm stem cuttings were used for each of the first four treatments. One of these four treatments involved treating the stock plant from which cuttings were to be taken with benomyl systemic fungicide, at a rate of 1.2 grams per liter. Another treatment involved dipping the cuttings in an aqueous solution of Captan and Terraclor at 2.4 grams, and 1.2 grams per liter respectively. A third treatment received both of the pre- and post-cutting treatments mentioned above. The fourth treatment was an untreated control.

Another ten treatments were conducted subsequently involving only 30 cm stem cuttings. These treatments involved allowing the cuttings to cure and form a layer of periderm over the cut surfaces. In five

of these treatments, the cuttings were placed in plastic bags to maintain a high level of humidity, and were cured in a controlled temperature chamber at 30°C. Another four treatments were cured in the open in a greenhouse. Some of the treatments received a post-curing fungicide treatment. These ten treatments were as follows:

TRT	Length of during period (days)	Cured in controlled chamber at 30°C	Cured in open greenhouse	Captan at 2.4 g/l	$CuSO_4$ at 0.6 g/l + D-M 45 at 0.9 g/l
1	2	X		X	
2	2	X			
3	2		X	X	
4	2		X		
5	4	X		X	
6	4	X			
7	4		X	X	
8	4		X		
9	4	X			
10	0 control				X

The fungicide-treated cuttings from these experiments were allowed to dry before being placed in the rooting medium. All cuttings were placed vertically in 100% sterile vermiculite.

Data were taken monthly, over a three month period, on the percentage of cuttings of each treatment surviving without rot. Seedling flats used for all of these experiments were sterilized in a 10% solution of chlorox prior to their use. The first four treatments were conducted under the Magoon Horticulture greenhouse conditions. The other ten were carried out in the Mid-Pacific Horticulture greenhouse.

RESULTS AND DISCUSSION

Plant Growth Investigations

The results of these experiments indicate that the terminal stems of Dracaena marginata are slow-growing, laying down an average of 0.9 cm of stem growth per month (Table 1). The increase in stem length varied from 0 cm to 4 cm per month depending upon the size and vigor of the branch as well as the weather conditions. Growth rate was faster during the warmer months and slower during the cool months of the year.

These plants produced an average of 3.4 nodes per month with a range of 0 to 12 nodes (Table 1). The production of nodes closely followed the growth rate of the stems, and a strong correlation exists between these phenomena. The stems had an average of 4.0 nodes per cm of growth.

The unfurling of leaves appeared quite independent of stem growth and node production, and was only mildly affected by environmental factors. Stems unfurled between 0 and 16 leaves each month with an average of 5.3 (Table 1).

Microscopic dissection of Dracaena marginata terminals indicated that an average of 32.6 nodes were present above the center of the bulge produced by the swollen leaf bases, and that on an average 22.8 leaves were present in the furled cluster. Growth is due to internodal elongation. Internodal elongation appears to be affected by the size of the branch, its position on the plant, and competition with other stems for nutrients and light. The available light, water, and

Table 1

Growth rate parameters for established plants of Dracaena marginata on the University of Hawaii Campus

Parameter	Avg.	Range	
		Max.	Min.
Increase in stem length (cm/mo.)	0.9 ± 0.2	4.0	0.0
Increase in no. of nodes/mo. and	3.4 ± 0.6	12.0	0.0
nodes per cm of stem	4.0 ± 0.6		
Increase in leaves unfurled/mo.	5.2 ± 0.04	16.0	0.0
Length of leaf retention (days)	187.2 ± 84.5	240+	59.0

Correlation between growth in cm and production of nodes: $r = 0.99$

mineral elements to the plant as a whole also affects the vigor of the stem.

The unfurling of leaves is controlled by the rate of growth of these leaves, and not by the growth of the stem, except where rapid elongation of the internodes in the region of the furled cluster causes an increased tension on the outer leaves in the cluster.

The portion of the stem below the bulge produced by overlapping swollen leaf bases with leaves present varied from about ten cm to 60 cm depending upon the size and vigor of the branch. An estimated average of 30 cm of leaf zone represents the display effect of most branches. Large, vigorous branches had larger leaf zones than slower growing narrow stems. Leaf abscission takes place throughout the year, and the individual stems seem to maintain a constant leaf to stem ratio. Abscission occurred sooner after unfurling when the stems on which the leaves were developing were less vigorous. Leaf abscission generally occurs at the bottom of the whorl of leaves, and rarely occurs from the center or the upper portions of it.

The growth patterns of 30 cm single-stemmed terminal plants in 15 cm plastic containers were similar to that mentioned above for the established plants (Table 3). The overall growth of these plants was faster however, possibly because of the applications of fertilizer during the middle of the investigation.

Leaves on these plants remained on the stem for an average of 175.5 days with a range of 59 to 243 days. These plants also had an estimated average of 30 cm of leaf zone per stem. The plants in general were short, about 50 cm high, providing a very large leaf to stem ratio.

Table 2

Growth rate parameters for 30 cm plants of *Dracaena marginata* in 15 cm plastic containers

Parameter	Avg.	Range	
		Max.	Min.
Increase in stem length (cm/mo.)	1.8 ± 1.1	6.5	0.0
Increase in no. of nodes/mo. and	5.4 ± 2.6	13.0	2.0
nodes per cm of stem	3.4 ± 0.8		
Increase in leaves unfurled/mo.	6.1 ± 2.4	15.0	0.0
Length of leaf retention (days)	175.5 ± 51.9	243.0	59.0

Correlation between growth in cm and production of nodes: $r = 0.98$

Stock Plant Management

Investigations of the sprout return of cut-back stems on well-established plants indicated that on the average 6.7 shoots were initiated per stem, 1.5 of these developed, and after an eight month period the shoots averaged 36.1 cm in length between the attachment of the new shoot to the main branch, and the tip of the furled cluster of leaves at the shoot tip (Table 3). An approximate conversion to the length of shoots between the parent stem and the apical meristem is presented in Fig. 2. The shoots, including both stems and leaves, averaged a 4.8 cm increase in growth each month. The rate of growth of these shoots increased progressively each month after their initiation. Shoot growth varied considerably with the vigor and size of the stem from which it developed. Rapidly growing watersprouts grew at a maximum rate of 19 cm in one month, while some shoots, particularly if they were growing on small less vigorous parent stems, or if they were competing against other lateral buds on the same stem, did not elongate at all for periods of over one month.

The position of the parent branch on the plant also had an effect on the growth of lateral buds on these stems. If the parent branch was a large dominant branch in a position on the plant where it received sufficient nutrients, and possibly sunlight, more shoots developed on this branch and the shoots elongated faster than those on obscure branches, with a diameter of less than 2.5 cm, that were at a disadvantage when competing with the rest of the plant for nutrients and such factors as light. The average branch diameter was about 3.5 cm. The largest branch diameter was about 4.5 cm.

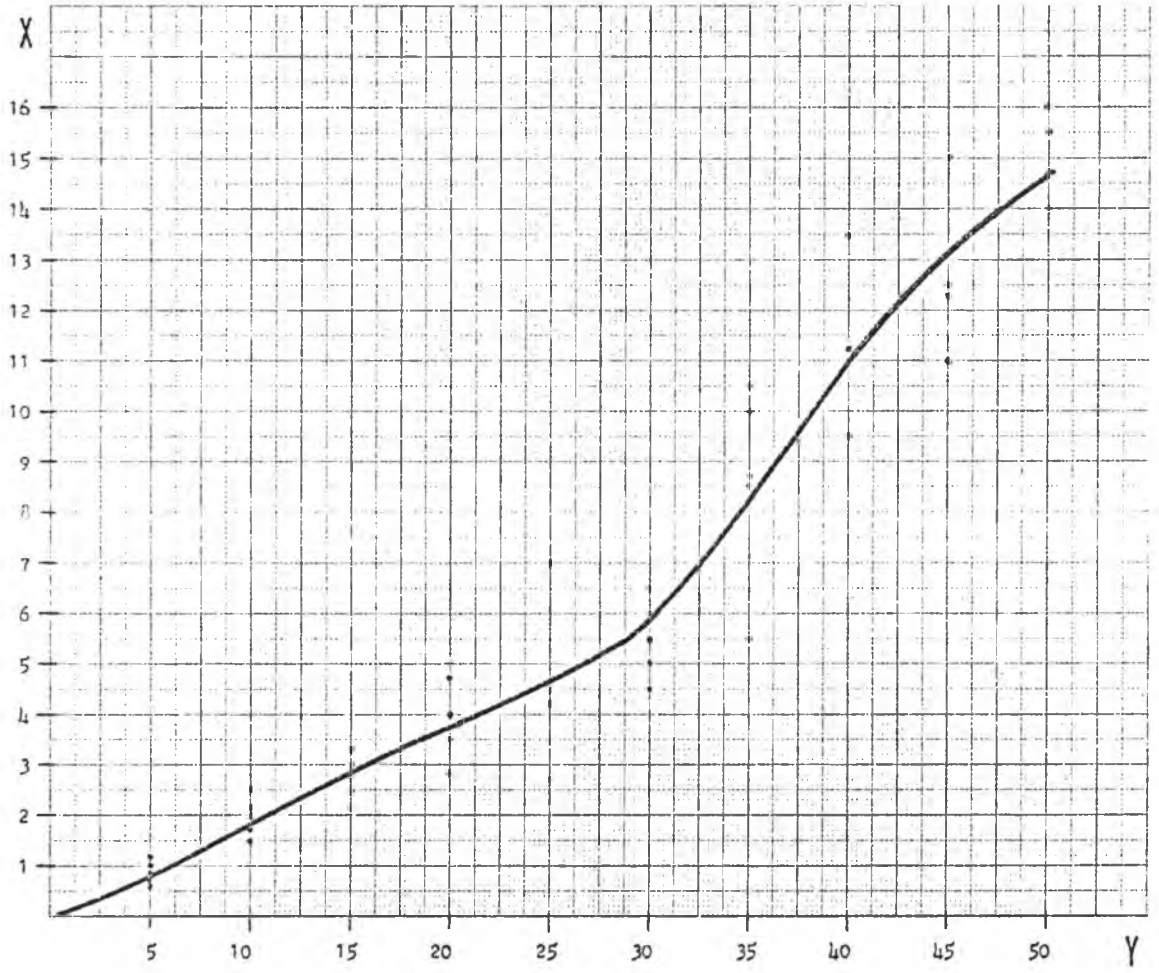
Table 3

Lateral shoot initiation, development, and growth on cut-back stems of well established *Dracaena marginata* stock plants

Parameter	Range Avg.	Min.	Max.
Shoots initiated/cut-back stem	6.7	13.0	3.0
Shoots developing/cut-back stem	1.5	3.0	1.0
Percent shoots developed/stem	23.8	60.0	15.4
Rate of increase in shoot length including leaves (cm/mo.)	4.8	19.0	0.0
Length of shoots after 8 mos. (cm)	36.0	93.0	6.5
Time to appearance of first leaf following cut back (days)	101.0		
Time to appearance of first normal sized leaf following cut back (days)	187.0		

Data presented are based on an average of 20 untreated cut-back stems of established stock plants. Data were taken over an eight month period, and averages representing the number of shoots developing, and the length of shoots are based on data collected eight months after cutting back.

Figure 2. Relationship between the length of developing shoots on cut-back stems of Dracaena marginata, as measured in terms of the distance in cm between the attachment of the shoot to the parent stem, and the tip of the furled cluster of leaves (Y axis), and as measured in terms of the distance between the attachment of the shoot to the parent branch and the center of the bulge produced near the meristem by overlapping swollen leaf bases (X axis). The curve on this graph represents an average of five stems of each length. The individual points represent the length of individual shoots.


X
16
15
14
13
12
11
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35
40
45
50
Y

It took an average of 101 days for the first identifiable leaf to appear on a new shoot, and 187 days for the first normal sized leaf to develop (Table 3). The duration of time between the initiation of the shoot, and the development of a normal sized leaf, and the length of a normal sized depended upon the size and vigor of the shoot on which it developed. The vigor of the shoot depends upon the vigor of the parent stem which is related to the size of the parent stem, its position on the plant, and such factors as available light, water, and mineral elements. The number of shoots developing on the cut-back stem also affects the growth rate of these shoots, as more shoots developing on a stem increases the inter-shoot competition for nutrients.

The application of growth regulators to enhance shoot development on cut-back stems of stock plants was somewhat successful (Table 4). The treatments did not significantly affect the number of shoots initiated (Table 5), but the increased concentrations of the chemicals significantly increased the number and percentage of these shoots developing (Tables 6 and 7). Aside from the chemicals, it appeared that the vigor, size, and position of the parent branch affected the number and percentage of shoots developing from them, but to a lesser degree than the chemicals.

The growth rate of the developing lateral shoots and leaves was also affected by the hormone treatments (Table 8). The difference between chemicals was not significant. This reduction in growth rate could be due not only to an inhibition of shoot elongation by the growth regulators, but a lack of competition between developing shoots on the control branches. Many of the untreated branches produced only one or two shoots, reducing the competition between these shoots.

Table 4

The effects of N_6BA, PBA, and ethephon on lateral shoot initiation and development of cut-back stems of established Dracaena marginata stock plants

Chemical	Conc. (ppm)	Avg. no. of shoots initiated	Avg. no. of shoots developed	Avg. percent shoots developed	Avg. length (cm) of shoots
N_6BA	1000	6.3	1.8	32.0	15.8
"	500	5.3	2.3	41.2	21.7
"	250	6.5	1.5	30.1	20.0
"	100	6.5	1.5	28.5	22.1
"	0	6.3	1.5	29.4	27.8
"	Avg.	6.2	1.7	32.3	21.5
PBA	1000	6.3	2.5	40.0	19.2
"	500	7.8	2.0	31.0	27.0
"	250	6.0	2.3	37.6	17.3
"	100	7.3	2.0	31.9	10.6
"	0	7.3	1.3	24.5	26.9
"	Avg.	6.9	2.0	33.0	20.2
Ethephon	1000	6.5	2.3	37.1	15.5
"	500	7.8	2.5	34.6	21.8
"	250	9.3	2.0	28.4	18.0
"	100	7.5	1.8	28.6	17.5
"	0	6.5	1.5	29.6	28.4
	Avg.	7.5	2.0	31.7	20.2

Four cut-back stems were used with each treatment. Data on shoot initiation are the total number of buds initiated per cut-back stem over the eight month period. Data on shoot development and length were collected at eight months after treatment.

Table 5

The effects of N_6BA, PBA, and ethephon on lateral shoot initiation of cut-back stems of established plants of Dracaena marginata

	Chemical	Concentration ppm 1000	500	250	100	0	Chem. Avg.
Avg. number of shoots initiated	N_6BA	6.3	5.3	6.5	6.5	6.3	6.2
	PBA	6.3	7.8	6.0	7.3	7.3	6.9
	Ethephon	6.5	7.8	9.3	7.5	6.5	7.5
	Conc. Avg.	6.3	6.9	7.3	7.1	6.7	

Differences due to chemicals F = 2.45 ns
Differences due to concentrations F = 0.42 ns
Differences due to initiation F = 0.92 ns

Table 6

The effects of N_6BA, PBA, and ethephon on the development of lateral shoots on cut-back stems of established plants of Dracaena marginata

	Chemical	Concentration ppm					Chem. Avg.
		1000	500	250	100	0	
Avg. number of shoots developed	N_6BA	1.8	2.3	1.5	1.5	1.5	1.7
	PBA	2.5	2.0	2.3	2.0	1.3	2.0
	Ethephon	2.3	2.5	2.0	1.8	1.5	2.0
	Conc. Avg.	2.2a	2.3a	1.9ab	1.8ab	1.4b	

Differences due to chemicals F = 1.64 ns
Differences due to concentrations F = 3.68 **
Differences due to interaction F = 0.78 ns

Treatments followed by the same letter are not significantly different at P = .01 [Duncan's Multiple Range Test (21)].

Table 7

The effects of N_6BA, PBA, and ethephon on the percentage of shoots developing on cut-back stems of established plants of *Dracaena marginata*

	Chemical	Concentration ppm					Chem. Avg.
		1000	500	250	100	0	
Avg. percent of shoots developed	N_6BA	32.0	41.2	30.1	28.5	29.4	32.3
	PBA	40.0	30.1	37.6	31.9	24.5	33.0
	Ethephon	37.1	34.6	28.4	28.6	29.6	31.7
	Conc. Avg.	36.4a	35.6a	32.0ab	29.7ab	27.8b	

Differences due to chemicals F = 0.22 ns
Differences due to concentrations F = 4.03 **
Differences due to interaction F = 1.90 ns

Treatments followed by the same letter are not significantly different at P = .01 [Duncan's Multiple Range Test (21)].

Table 8

The effects of N_6BA, PBA, and ethephon on the length (cm) of developing lateral shoots and leaves on cut-back stems of Dracaena marginata stock plants after eight months

	Chemical	Concentration ppm 1000	500	250	100	0	Chem. Avg.
Avg. length (cm) of developing shoots	N_6BA	15.8	21.7	20.0	22.1	27.8	21.5
	PBA	19.2	27.0	17.3	10.6	26.9	20.2
	Ethephon	15.5	21.8	18.0	17.5	28.4	20.2
	Conc. Avg.	16.8b	23.5ba	18.46b	16.7b	27.7a	

Differences due to chemicals F = 0.12 ns
Differences due to concentrations F = 3.46 *
Differences due to interaction F = 0.58 ns

Treatments followed by the same letter are not significantly different at P = .05 [Duncan's Multiple Range Test (21)].

The plants receiving no cytokinin produced the greatest number of shoots reaching ten cm between the parent stem and the center of the bulge produced by the cluster of swollen leaf bases near the apical meristem (Table 9). The smaller number of shoots produced on the cytokinin-treated plants may be explained by the fact that the first set of shoots developing on the untreated plants grew to a length of ten cm faster than those produced on the cytokinin treated plants, allowing the next flush to be produced earlier on the untreated plants. This allowed two cutting periods for these plants, and a cumulative greater number of shoots produced over the eight month period. The decreased growth rate of shoots developing on cytokinin treated plants may be due to an inhibition of elongation by the PBA, or to competition between the shoots.

Vegetative Propagation

The effects of light intensity were not significant with regards to rooting and shoot development of the 30 cm stem pieces (Table 10). The cuttings rooted slightly faster under low light conditions (450 ft candles), and shoot initiation and development were also enhanced by the low light regime. The length of developing lateral buds was slightly greater under the high light condition. This could be due to a reduction in the competition between shoots, as there were fewer shoots produced on the cuttings propagated under the high light conditions. The photosynthetic rate could also be greater under high light providing a greater level of carbohydrate for these shoots.

The ten cm terminal cuttings rooted more rapidly under the high light regime (Table 10). The increased light would provide more energy

Table 9

The effects of five different stock plant management schemes on the number of shoots reaching ten cm in length over an eight month period

Treatment	Plant no.	Date 1/27	2/27	3/27	4/27	5/27	6/27	7/27	8/27	Sum	Avg.
a. Cut-back stems, remove new shoots at 10 cm	1						2			2	2.5
	2				1				2	3	
b. Same as a but cut-back parent stem below lowest 10 cm shoot	1					1				1	2.5
	2				2				2	4	
c. Same as a but trt. cut-back stem w/PBA at 1000 ppm	1						1			1	1.5
	2					1			1	2	
d. Same as b but trt. cut-back stem w/PBA at 1000 ppm	1						2			2	2.0
	2						2			2	
e. Cut-back stems, trt. w/PBA, cut back new shoots and trt. w/PBA	1						2			2	2.0
	2					2				2	

Data represent the number of shoots that reached 10 cm in length between the parent stem and overlapping swollen leaf bases at each month.

Table 10

The effects of light intensity on the rooting and lateral shoot initiation and development of 30 cm stem cuttings, and the rooting of ten cm terminal cuttings of Dracaena marginata

	Low light			High light		
	Mo. after striking cuttings			Mo. after striking cuttings		
	Mo. 1	Mo. 2	Mo. 3	Mo. 1	Mo. 2	Mo. 3
Root index (stem pieces)	36	46	52	36	42	50
Avg. no. of shoots initiated			7.7			5.4
" " " " developed			2.1			1.8
% shoots developed			30.3			40.5
Avg. length of shoots (cm)			2.0			2.3
Root index terminals	48	76	94	68	94	100

Effect of light on shoot initiation t = 2.02 ns
" " " " " development t = 1.12 ns
" " " " % shoots developed t = 1.13 ns
" " " " shoot length t = 0.34 ns

for photosynthesis, which would result in the production of a greater quantity of carbohydrate and possibly certain rooting co-factors.

The use of mist had several important effects on rooting and lateral bud development (Table 11). With both the 30 cm stem cuttings, and ten cm terminal cuttings, rooting was promoted by the use of intermittent mist. This effect may be due to a lack of desiccation. With the 30 cm cuttings the mist also enhanced the number of shoots initiated, but had no significant effect on the number or percentage of these shoots developing.

The effect of misting on the length of shoots developing on the 30 cm stem cuttings was also significant, with those propagated out of the mist elongating much more rapidly. The shoots developing on cuttings under mist were extremely chlorotic indicating that the mist could have leached nutrients from the leaves. This lack of nutrients could explain, at least in part, the slower growth rate of these shoots. The cuttings propagated out of the mist were also exposed to much warmer temperatures and this may have resulted in an increased rate of metabolic activity of these cuttings. The cuttings propagated under mist received 100% natural light intensity, while those not under mist received 50% natural sunlight.

The effects of the orientation of cuttings on rooting and sprout development were quite notable. The vertical orientation was significantly better for promoting shoot development with both the 30 cm and ten cm stem pieces (Tables 12 and 13). The orientation did not significantly influence the number of shoots initiated, but cuttings

Table 11

The effects of intermittent mist on rooting and lateral shoot initiation and development of 30 cm stem cuttings, and rooting of ten cm terminal cuttings of *Dracaena marginata*

	Mist			No mist		
	Mo. after striking cuttings			Mo. after striking cuttings		
	Mo. 1	Mo. 2	Mo. 3	Mo. 1	Mo. 2	Mo. 3
Root index (stem pieces)	42	52	72	44	58	64
Avg. no. of shoots initiated			8.5			5.6
" " " " developed			2.2			1.9
% shoots developed			36.0			46.6
Avg. length of shoots (cm)			3.1			6.5
Root index (terminals)	74	100	100	66	80	84

Effect of mist on shoot initiation t = 2.14 *
" " " " " development t = 0.89 ns
" " " " % shoots developed t = 1.26 ns
" " " " shoot length t = 2.13 *

Table 12

The effects of orientation on rooting, and lateral shoot initiation and development of 30 cm stem cuttings of Dracaena marginata

	Vertical orientation			Horizontal orientation		
	Mo. after striking cuttings			Mo. after striking cuttings		
	Mo. 1	Mo. 2	Mo. 3	Mo. 1	Mo. 2	Mo. 3
Root index	38	62	70	30	36	38
Avg. no. of shoots initiated			7.3			4.8
" " " " developed			2.1			1.1
% shoots developed			45.8			24.7
Avg. length of shoots (cm)			4.5			4.5

Effects of orientation on shoot initiation	t = 1.32 ns
" " " " " development	t = 2.55 *
" " " " the % shoots developed	t = 1.61 ns
" " " " shoot length	t = 0.02 ns

Table 13

The effects of orientation on rooting, and lateral shoot initiation and development of ten cm stem cuttings of *Dracaena marginata*

	Vertical orientation			Horizontal orientation		
	Mo. after striking cuttings			Mo. after striking cuttings		
	Mo. 1	Mo. 2	Mo. 3	Mo. 1	Mo. 2	Mo. 3
Root index	36	50	60	32	36	38
Avg. no. of shoots initiated			6.2			3.6
" " " " developed			1.3			0.3
% shoots developed			22.6			13.9
Avg. length of shoots (cm)			4.4			7.5

Effects of orientation on shoot initiation t = 1.15 ns
" " " " " development t = 3.33 **
" " " " % shoots developed t = 2.14 *
" " " " shoot length t = 0.28 ns

placed vertically in the medium did appear to initiate more buds than horizontally positioned cuttings. The effect on the development of shoots with the ten cm cuttings was highly significant.

The vertical position also had a positive effect on the rate of root development, for both cutting sizes, due to less desiccation.

Although the horizontally placed cuttings had a greater surface area in contact with the medium, they were confined to the upper 0.5 to 2 cm of the medium which became desiccated very rapidly in the warm greenhouse. The horizontal cuttings displayed signs of desiccation such as a wrinkling of the epidermis, and in some cases a complete drying out of the tissues. The bottom end of the vertical cuttings were placed to a depth of from five to seven cm in the medium which held moisture for a much longer period of time. This problem could be overcome if the horizontally oriented cuttings were propagated under mist.

The initial purpose of placing cuttings horizontally in the medium was to determine whether this would allow more shoots to develop along the upper surface of the cutting. It appears, however, that all roots are produced from the basal end of the cutting, and all shoots develop at the apical end of the cutting, regardless of their orientation in the medium. No roots or shoots developed along the cuttings between these points (Fig. 3).

The age or stage of development of the cuttings greatly affected root development (Table 14). With the 30 cm stem cuttings there was a definite increase in rooting as the maturity of the cuttings increased.

Figure 3. Rooting and sprout return from cuttings oriented horizontally in the rooting medium. All roots were produced at the bottom end (A), and shoots were produced at the upper end of the cutting (B).

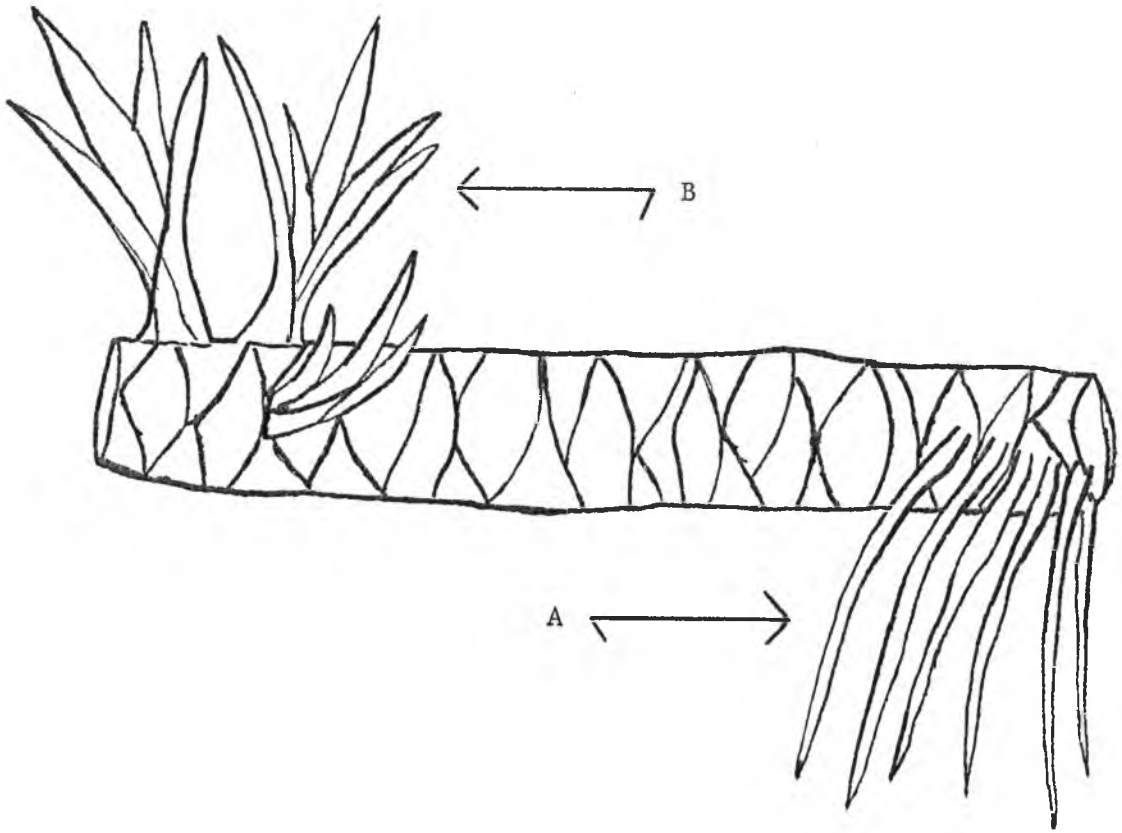
B
A

Table 14

The effects of age or stage of maturity of the cutting material on rooting and lateral shoot initiation and development of 30 cm and ten cm cuttings of Dracaena marginata

	30 cm cuttings			ten cm cuttings		
	Mo. after striking cuttings			Mo. after striking cuttings		
	Mo. 1	Mo. 2	Mo. 3	Mo. 1	Mo. 2	Mo. 3
Hardwood cuttings						
Root index	46	82	88	46	78	80
Avg. no. of shoots initiated			6.30			3.80
" " " " developed			2.0			0.80
% shoots developed			35.62			28.33
Avg. length of shoots (cm)			6.06			5.26
Semi-hardwood cuttings						
Root index	42	64	64	28	38	38
Avg. no. of shoots initiated			6.89			3.80
" " " " developed			1.90			0.70
% shoots developed			31.82			15.92
Avg. length of shoots (cm)			11.44			9.61
Greenwood cuttings						
Root index	32	38	42	64	90	92
Avg. no. of shoots initiated			4.5			
" " " " developed			1.3			
% shoots developed			35.5			
Avg. length of shoots (cm)			1.7			

Effects of age on shoot length:
Array: Greenwood: 1.70 cm a
Semi-hardwood: 11.44 cm b
Hardwood: 6.89 cm b

Effects of age on shoot initiation F = 1.47 ns t = 0.0 ns
" " " " development F = 2.14 ns t = 0.27 ns
" " " " % shoots developed F = 0.05 ns t = 1.32 ns
" " " " length of shoots F =17.79 ** t = 0.93 ns

Treatments followed by the same letter are not significantly different at P = 0.01 [Duncan's Multiple Range Test (21)].

No data were recorded on shoot development for ten cm greenwood cuttings, as these were terminal cuttings.

This same trend was followed by the ten cm cuttings, except for the terminal cuttings which rooted the best.

Shoot initiation and early development were not significantly affected by the maturity of the cuttings, but the length of shoots developing on the 30 cm cuttings was greatly affected (Table 14). The elongation of shoots on the greenwood cuttings was considerably less than that of both the semi-hardwood and hardwood cuttings. This could be due to a greater amount of stored carbohydrate in the older wood, or because of the larger diameter of these cuttings. Both factors probably play a role in the growth rate of the shoots developing on the cuttings.

A problem noted with the greenwood cuttings is that very succulent material taken from watersprouts became desiccated quite readily under warm greenhouse conditions. This was evidenced by a shriveling and drying of the upper portions of these cuttings. This resulted in fewer of the greenwood cuttings producing shoots, and the desiccation also retarded root development. Greenwood cuttings taken from moderately or slowly growing terminal branches with short internodes appeared quite tolerant to the dry conditions, and few of these were lost due to desiccation. The ten cm terminals which were comprised largely of this type of material were also quite tolerant to desiccation.

The semi-hardwood cuttings appeared to be the most susceptible to bacterial soft rot caused by Erwinia carotovora, the factor causing the heaviest loss of this cutting material. These semi-hardwood cuttings were however very tolerant to desiccation. The greenwood stem cuttings were much less susceptible to the bacterial rot than the semi-hardwood

cuttings. This susceptibility to rot by the semi-hardwood cuttings may be associated with a number of factors. The tissues may have a greater amount of systemic or surface pathogens because they have been present on the plant for a long period of time. They may also have less nitrogen than the very young tissue, and less stored carbohydrate than the older tissue, being at a disadvantage with regards to nutrition. The nutritional status and vigor of a cutting or plant has a considerable effect upon its susceptibility to disease. The hardwood cuttings were the least susceptible to soft rot and desiccation. They rooted readily and produced vigorous lateral shoots.

The application of IBA to the cuttings appeared to enhance rooting (Tables 15 and 16). There was an increase in the level of rooting with each increase in IBA concentration except at 4000 ppm where there was a slight decrease in rooting compared to the 3000 ppm concentration.

PBA applied as an aqueous spray at 1000 ppm to the stock plant greatly inhibited the rooting of cuttings taken from these plants. When IBA was applied to these cuttings, they responded more nearly like the untreated control. PBA when applied to the cuttings at the time of propagation had no apparent effect on root initiation or development, and cuttings receiving such treatments responded similarly to the untreated control. The application of PBA at 1000 ppm to the upper portion of the cutting, with IBA at 3000 ppm applied to the lower portion of the cutting at the time of propagation had a very positive effect on rooting with a greater rooting index than all treatments. Both the 30 cm and ten cm cuttings responded similarly to the combined PBA (top) and IBA (basal) application.

Table 15

The effects of hormone treatments on root development of 30 cm stem cuttings of Dracaena marginata

PBA applied to stock plant at 1000 ppm	PBA applied to cutting at 1000 ppm	IBA (ppm)	Root index		
			Mo. 1	Mo. 2	Mo. 3
		1000	28	38	48
		2000	26	42	54
		3000	38	70	84
		4000	28	46	58
Control			26	30	38
X			20	20	26
X		3000	32	34	38
	X		32	38	38
	X	3000	50	74	90

The maximum and minimum indexes possible with these calculations are 100 and 20 respectively.

Table 16

The effects of hormone treatments on root development of stem and terminal ten cm cuttings of Dracaena marginata

PBA applied to stock plant at 1000 ppm	PBA applied to cutting at 1000 ppm	IBA (ppm)	Root index		
			Mo. 1	Mo. 2	Mo. 3
Stem cuttings					
		3000	42	70	78
X			24	24	24
X		3000	28	30	32
	X		32	34	36
	X	3000	38	80	90
Control			24	26	32
Terminal cuttings					
		3000	76	100	100
Control			55	82	98

The maximum and minimum indexes possible with these calculations are 100 and 20 respectively.

The ten cm terminal cuttings rooted readily with or without IBA treatment, but rooted better with the treatment.

Auxins are known to promote root initiation of cuttings, but at above optimal concentrations, a negative effect on rooting often occurs. These data indicate that the optimum concentration of IBA for stimulating root initiation of Dracaena marginata cuttings is around 3000 ppm, or between 2000 and 4000 ppm. Cytokinins are known to inhibit root initiation and development of cuttings, and this could explain the poor rooting response of cuttings taken from the PBA treated stock plants. The entire stem from which the cuttings were taken received the PBA treatment just four days prior to taking cuttings. Cytokinins are also known to have slow movement in most plant tissues. PBA when applied only to the upper portion of the cutting at the time of propagation would probably not be translocated to the rooting zone in sufficient quantities to inhibit rooting. The PBA induced nucleic acid metabolism in the upper portion of the cuttings, could result in the production of substances that promote rooting, such as sugars or certain rooting cofactors, that would be translocated to the rooting zone of the cuttings. This would result in an increase in rooting, and may explain the increase in root development of cuttings that received both IBA and PBA treatments to the cuttings at the time of propagation.

The rapid rooting of terminal cuttings with or without IBA treatment could be due to the production of substances in the leaves that promote rooting. Auxins are produced in the young leaves and meristems of many plants, and are translocated down the stem. Aside from auxins,

certain cofactors are necessary for rooting and the source of these cofactors is usually the leaves. These cofactors may include sugars, nitrogenous materials, and certain phenolic compounds (55). The application of IBA to the terminals probably supplied additional auxin to the rooting zone, and accelerated root initiation and development.

The use of chemicals to stimulate lateral shoot development of cuttings appears quite effective (Tables 17-27). There was a general increase in the number of shoots developing with each increase in chemical concentration except with 1000 ppm, where PBA, and N_6BA showed a slight reduction in shoot development with the 30 cm cuttings when compared to the 500 ppm concentration. Ethephon was the most effective chemical (Tables 17 and 18).

The effects of chemicals on the number of shoots initiated by the cuttings was not significant for either the 30 cm or ten cm cuttings (Tables 19 and 20). Despite the lack of significance, there was a slight decrease in the number of shoots initiated with each increase in chemical concentration with ethephon when applied to the 30 cm cuttings (Table 19). There was no uniform response with regards to the number of shoots initiated with the other treatments.

The numbers of shoots which actually developed were significantly affected by the treatments (Tables 21 and 22). With the 30 cm cuttings, the results were highly significant for the differences between chemicals. All levels of concentration were significant over the control, and ethephon was significant over N_6BA. The most effective treatment for ethephon was 1000 ppm, while both N_6BA and PBA were most effective at 500 ppm. With the ten cm cuttings, there was significance

Table 17

The effects of N_6BA, PBA, and ethephon on lateral shoot initiation and development of 30 cm cuttings of Dracaena marginata

Chemical	Conc. (ppm)	Avg. no. of shoots initiated	Avg. no. of shoots developed	Avg. percent shoots developed	Avg. lengths of shoots (cm)
N_6BA	1000	5.6	2.1	39.2	15.4
"	500	6.5	2.5	38.6	14.5
"	250	6.6	2.3	35.0	15.9
"	100	6.1	2.0	32.9	16.7
"	0	6.2	1.9	30.8	18.2
"	Avg.	6.2	2.2	35.3	16.1
PBA	1000	6.3	2.5	39.8	15.0
"	500	6.7	2.7	40.4	13.8
"	250	6.5	2.5	38.4	14.4
"	100	7.5	2.4	32.6	15.9
"	0	6.2	1.8	29.5	17.6
"	Avg.	6.6	2.4	36.1	15.3
Ethephon	1000	5.8	3.0	54.7	14.7
"	500	5.9	2.9	49.6	14.9
"	250	6.1	2.6	42.8	16.2
"	100	6.2	2.5	40.7	15.8
"	0	6.4	1.8	28.6	18.1
"	Avg.	6.1	2.6	43.3	15.9

Averages compiled for ten cuttings of each treatment. The number of shoots initiated represents the average of the total number of shoots initiated on each cutting per treatment. The number of shoots developing and the length of shoots represent data taken at three months after treatment.

Table 18

The effects of N_6BA, PBA, and ethephon on lateral shoot initiation and development of ten cm cuttings of Dracaena marginata

Chemical	Conc. (ppm)	Avg. no. of shoots initiated	Avg. no. of shoots developed	Avg. percent shoots developed	Avg. length of shoots (cm)
N_6BA	1000	5.7	1.5	26.8	11.1
"	500	6.4	1.5	25.5	11.3
"	250	6.7	1.2	18.7	11.6
"	100	5.6	1.5	29.1	10.7
"	0	5.5	1.3	23.9	11.7
"	Avg.	6.0	1.4	24.8	11.3
PBA	1000	6.3	2.0	31.6	12.1
"	500	6.6	1.9	31.7	10.5
"	250	5.9	1.5	27.6	11.2
"	100	6.3	1.8	30.0	10.0
"	0	5.9	1.4	24.3	12.1
"	Avg.	6.2	1.7	29.0	11.2
Ethephon	1000	5.9	2.0	36.3	10.1
"	500	5.3	2.1	40.8	11.2
"	250	6.7	1.7	25.7	9.7
"	100	6.1	1.6	26.4	9.8
"	0	6.2	1.2	20.2	11.4
"	Avg.	6.0	1.7	29.9	10.5

Averages compiled for ten cuttings of each treatment. The number of shoots initiated represents the average of the total number of shoots initiated on each cutting per treatment. The number of shoots developing and the length of shoots represent data taken at three months after treatment.

Table 19

The effects of N_6BA, PBA, and ethephon on lateral shoot initiation of 30 cm cuttings of Dracaena marginata

	Chemical	Concentration ppm					Chem. Avg.
		1000	500	250	100	0	
Avg. number of shoots initiated	N_6BA	5.6	6.5	6.6	6.1	6.2	6.2
	PBA	6.3	6.7	6.5	7.5	6.2	6.6
	Ethephon	5.8	5.9	6.1	6.2	6.4	6.1
	Conc. Avg.	5.9	6.4	6.4	6.6	6.3	

Differences due to chemicals F = 2.62 ns
Differences due to concentrations F = 1.19 ns
Differences due to interaction F = 0.85 ns

Average number of shoots initiated using ten cuttings per treatment over a three month period.

Table 20

The effects of N_6BA, PBA, and ethephon on lateral shoot initiation of ten cm cuttings of Dracaena marginata

	Chemical	Concentration ppm					Chem. Avg.
		1000	500	250	100	0	
Avg. number of shoots initiated	N_6BA	5.7	6.4	6.7	5.6	5.5	6.0
	PBA	6.3	6.6	5.9	6.3	5.9	6.2
	Ethephon	5.9	5.3	6.7	6.1	6.2	6.0
	Conc. Avg.	6.0	6.1	6.4	6.0	5.9	

Differences due to chemicals F = 0.27 ns
Differences due to concentrations F = 0.58 ns
Differences due to interaction F = 1.01 ns

Average number of shoots initiated using ten cuttings per treatment over a three month period.

Table 21

The effects of N_6BA, PBA, and ethephon on the average number of shoots developed after three months on 30 cm cuttings of Dracaena marginata

	Chemical	Concentration ppm 1000	500	250	100	0	Chem. Avg.
Avg. number of shoots developed	N_6BA	2.1	2.5	2.3	2.0	1.9	2.2j
	PBA	2.5	2.7	2.5	2.4	1.8	2.4jk
	Ethephon	3.0	2.9	2.6	2.5	1.8	2.6k
	Conc. Avg.	2.5a	2.7a	2.5a	2.3a	1.8b	

Differences due to chemicals F = 4.38 *
Differences due to concentration F = 7.16 **
Differences due to interaction F = 0.76 ns

Treatments within the same source of variation and followed by the same letter are not significantly different [Duncan's Multiple Range Test (21)]. With differences due to chemicals, separations are based on P = .05, and with differences due to concentrations P = .01.

Table 22

The effects of N_6BA, PBA, and ethephon on the average number of shoots developed after three months on ten cm cuttings of Dracaena marginata

	Chemical	Concentration ppm					Chem. Avg.
		1000	500	250	100	0	
Avg. number of shoots developed	N_6BA	1.5	1.5	1.2	1.5	1.3	1.4j
	PBA	2.0	1.9	1.5	1.8	1.4	1.7k
	Ethephon	2.0	2.1	1.7	1.6	1.2	1.7k
	Conc. Avg.	1.8a	1.8a	1.5b	1.6b	1.3b	

Differences due to chemicals F = 4.29 *
Differences due to concentrations F = 4.10 **
Differences due to interaction F = 0.64 ns

Treatments within the same source of variation and followed by the same letter are not significantly different [Duncan's Multiple Range Test (21)]. With differences due to chemicals, separation are based on P = .05, and with differences due to concentrations P = .01.

Table 23

The effects of N_6BA, PBA, and ethephon on the percentage of shoots developing after three months on 30 cm cuttings of Dracaena marginata

	Chemical	Concentration ppm					Chem. Avg.
		1000	500	250	100	0	
Avg. percentage of shoots developing	N_6BA	38.7	38.4	36.2	34.9	34.0	36.4j
	PBA	39.1	39.5	38.3	34.8	32.7	36.9k
	Ethephon	47.8	44.8	40.9	39.6	32.2	41.0k
	Conc. Avg.	41.8a	40.9ab	38.5bc	36.4e	33.0d	

Differences due to chemicals F = 16.83**
Differences due to concentrations F = 19.96**
Differences due to interaction F = 2.55*

Treatments within the same source of variation and followed by the same letter are not significantly different at P = .01 [Duncan's Multiple Range Test (21)].

Table 24

Differences due to the interaction between chemicals and concentrations, regarding the effects of N_6BA, PBA, and ethephon on the percentage of shoots developing on 30 cm cuttings of Dracaena marginata [Duncan's Multiple Range Test (21)]

Chemical	Conc. (ppm)	Avg. % shoots developed	Conclusion
Ethephon	1000	54.67	
"	500	49.57	
"	250	42.83	
"	100	40.69	
PBA	500	40.44	
"	1000	39.78	
N_6BA	1000	39.24	
"	500	38.59	
PBA	250	38.36	
N_6BA	250	35.02	
"	100	32.94	
PBA	100	32.61	
N_6BA	0	30.77	
PBA	0	29.46	
Ethephon	0	28.60	

Treatments covered by the same line are not significantly different at P = .05.

Table 25

The effects of N_6BA, PBA, and ethephon on the percentage of shoots developing after three months on ten cm cuttings of Dracaena marginata

	Chemical	Concentration ppm 1000	500	250	100	0	Chem. Avg.
Avg. percentage of shoots developing	N_6BA	30.8	29.8	25.3	32.1	29.0	29.4
	PBA	33.9	33.9	31.2	32.7	29.2	32.2
	Ethephon	36.7	39.6	30.1	30.7	26.4	32.7
	Conc. Avg.	33.8ab	34.4a	28.9bc	31.8abc	28.2c	

Differences due to chemicals F = 2.69 ns
Differences due to concentrations F = 4.17 **
Differences due to interaction F = 1.32 ns

Treatments followed by the same letter are not significantly different at P = .01 [Duncan's Multiple Range Test (21)].

Table 26

The effects of N_6BA, PBA, and ethephon on the length of shoots developing on 30 cm cuttings of Dracaena marginata

	Chemical	Concentration ppm 1000	500	250	100	0	Chem. Avg.
Avg. length of shoots developed (cm)	N_6BA	15.4	14.5	16.0	16.7	18.2	16.1
	PBA	15.0	13.8	14.4	15.9	17.6	15.3
	Ethephon	14.7	14.9	16.2	15.8	18.0	15.9
	Conc. Avg.	15.1a	14.4a	15.5ab	16.1ab	17.9b	

Differences due to chemicals F = 0.40 ns
Differences due to concentrations F = 2.53 *
Differences due to interaction F = 0.10 ns

Treatments followed by the same letter are not significantly different at P = .05 [Duncan's Multiple Range Test (21)].

Average length of shoots developed was measured using ten cuttings per treatment, at three months after treatment.

Table 27

The effects of N_6BA, PBA, and ethephon on the length of shoots developing on ten cm cuttings of Dracaena marginata

	Chemical	Concentration ppm 1000	500	250	100	0	Chem. Avg.
Avg. length of shoots developed (cm)	N_6BA	11.1	11.3	11.7	10.7	11.7	11.3
	PBA	12.1	10.5	11.2	10.0	12.1	11.2
	Ethephon	10.1	11.2	9.7	9.8	11.4	10.5
	Conc. Avg.	11.1	11.0	10.9	10.2	11.8	

Differences due to chemicals F = 1.55 ns
Differences due to concentrations F = 1.48 ns
Differences due to interaction F = 0.58 ns

Average length of shoots developed measured using ten cuttings per treatment, at three months after treatment.

for both the differences between chemicals, and concentrations (Table 22). Both 1000 and 500 ppm were significant over the untreated control, and both ethephon and PBA were superior to N_6BA.

The percentage of shoots developing on both the 30 cm and ten cm cuttings followed the results for the number of shoots developing quite closely (Tables 23, 24, and 25). With the 30 cm cuttings, the effects of concentration and chemicals were both highly significant (Tables 23 and 24). With concentration there was significance between a number of treatments (Table 23). Considering the difference among chemicals, ethephon was significantly more effective than both N_6BA and PBA. With the ten cm cuttings there was no significant difference between the chemicals tested, but a high level of significance existed among the concentrations (Table 25). As shown in Table 23, for 30 cm cuttings the most effective treatments were those at 1000 and 500 ppm, with the single most effective being ethephon at 1000 ppm. With the ten cm cuttings the single most effective treatment was ethephon at 500 ppm.

With the length of shoots developing on these cuttings, no significance was found with the ten cm cuttings, and with the 30 cm cuttings the results were marginally significant for the effects of concentration only (Tables 26 and 27). This significance existed between both 500 and 1000 ppm as compared to the untreated control. There was a depressed effect with the higher concentrations of the chemicals on shoot elongation (Tables 17 and 18). This effect was more marked with the 30 cm cuttings than with the ten cm cuttings.

Cytokinins have been shown to reduce the growth rate of shoots developing from treated stems (33). There was a significant decrease

in the average length of the shoots developing on the stems treated with the two highest concentrations of the hormones, but this would impose a greater level of competition between these shoots. It may be this inter-shoot competition that is creating the level of significance between the rates of shoot elongation, rather than an inhibitory effect of the hormone treatment.

The differences among the percentage of shoots developing were controlled primarily by the number of shoots developing, not by the number initiated because the number initiated did not vary considerably between treatments.

It appears that Dracaena marginata is capable of initiating many more shoots than can develop on a cutting, and that treating the cuttings with chemicals does not affect the number of shoots that will be initiated. The chemicals utilized in these experiments were however applied only to the upper seven cm of the cuttings, and perhaps if the entire stem were treated more shoots would be initiated. The number and percentage of breaks developing into shoots was significant, indicating that the role of the chemical is perhaps to overcome apical dominance induced by the auxin produced by these newly initiated shoots, allowing more of them to begin to develop.

Disease Control

Among the first four treatments, the post-cutting dip in Captan and Terraclor gave the best protection against rotting (Table 28). The benomyl systemic fungicide applied to the stock plant was the least effective treatment and had a lower number of cuttings surviving than

Table 28

The effects of disease preventive treatments (without curing) on infection and rotting of *Dracaena marginata* cuttings

Benomyl at 1.2 g/l to stock plant	Post-cutting Captan at 2.4 g/l + Terraclor at 1.2 g/l	Cutting size (cm)	Percentage cuttings surviving without infection		
			Mo. 1	Mo. 2	Mo. 3
+		30	80	10	0
+		10	30	0	0
	+	30	100	100	0
	+	10	100	20	20
+	+	30	100	90	50
+	+	10	60	0	0
Control		30	100	90	30
Control		10	50	10	0

the untreated control. The treatment of cuttings with a post-cutting dip in Captan and Terraclor increased survival. With these four treatments, and with most experiments in general, the ten cm cuttings rotted much more readily than did the 30 cm cuttings. This could have been due to a number of factors. The cuttings were small, and did not have as much tissue to support developing roots and shoots. This rapid depletion of food reserves in the tissues may have resulted in weaker cuttings, less resistant to pathogens. Many of the ten cm cuttings came from greenwood and semi-hardwood material which appears to be more susceptible to diseases.

The other ten treatments indicated that allowing the cuttings to cure and form a layer of periderm greatly reduces the susceptibility of the cuttings to pathogens (Table 29). The most effective treatment (No. 7) was curing the cuttings for four days in an open greenhouse and then dipping the cuttings with Captan prior to placing them in the rooting medium. All of these cuttings survived for three months with no apparent infection. The post-curing Captan dip at 2.4 grams per liter appears to be very important. Curing the cuttings is also important, and better results were obtained when the cuttings were cured in the open greenhouse rather than in the controlled temperature chamber. Cuttings in the chamber were kept in plastic bags, and the high relative humidity and warm temperature promoted the development of fungal growth on the cuttings. The fungus was Fusarium moniliforme, and may have been present on or in the cuttings before curing. It may be necessary to improve the surface sterilization of the cuttings prior to curing. These cuttings were given a one minute drench in 5% chlorox as a pre-curing surface sterilization treatment.

Table 29

The effects of disease preventive treatments (including curing) on infection and rotting of *Dracaena marginata* cuttings

Treatment	Length of curing period (days)	Cured in controlled chamber at 30°C	Cured in open greenhouse	Captan at 2.4 g/l post-cure appl.	$CuSO_4$ at 0.6 g/l + D-M 45 at 0.9 g/l post-cure appl.	Percentage cuttings surviving without infection		
						Mo. 1	Mo. 2	Mo. 3
1	2	X		X		80	60	20
2	2	X				50	40	20
3	2		X	X		100	90	90
4	2		X			80	50	50
5	4	X		X		100	70	30
6	4	X				80	40	10
7	4		X	X		100	100	100
8	4		X			80	60	50
9	4	X			X	100	70	0
10	0	Control				80	30	30

The post-curing Captan drench may prevent infection by Erwinia by inhibiting the bacteria itself, or indirectly by preventing fungus invasions that would provide avenues of entry for the bacteria. The benomyl systemic fungicide possibly caused more detriment to the cuttings by preventing or delaying periderm formation.

Post-curing drenches of the combination of basic copper sulfate and Dithane M-45 did not successfully prevent infection by Erwinia.

The most effective treatment tested appears to be the combination of allowing the cuttings to cure for at least four days in an open greenhouse, followed by a post-curing drench of the cuttings in Captan at 2.4 g per liter of water. Cuttings taken from succulent material, and cured in the open greenhouse became desiccated however, while cuttings cured in plastic bags in a controlled temperature chamber showed no sign of desiccation. If an effective means of eliminating the fungi present on or in the cuttings prior to curing could be developed, the use of the controlled chambers could prove to be very valuable.

CONCLUSIONS

Under the conditions of these experiments the growth rate of this species is slow, with monthly increases in stem length averaging 0.9 cm over an eight month period. The proper manipulation of the environmental factors could result in faster growth, providing a faster production of propagating material on a stock plant.

The development of lateral buds on cut-back stems is promoted by the use of N_6BA, PBA, and ethephon. The elongation of the shoots was slightly depressed by the use of the higher concentrations of the chemicals, either due to the chemical inhibition of shoot elongation, or because of increased competition between shoots due to a greater number of shoots developing on the stems treated with the higher concentrations of the chemicals. It does appear however that these chemicals can be utilized to the practical advantage of increasing the number of lateral shoots developing on stock plants.

In general, the optimum environmental conditions for propagating stem cuttings appears to be the use of hardwood cutting material, intermittent mist, high light intensity (over 7000 foot candles), and vertical orientation in the rooting medium. Terminal cuttings rooted faster than stem cuttings in these experiments.

Applications of IBA are effective in hastening rooting of both stem cuttings and terminals. The most effective concentration of IBA is around 3000 ppm. A single application of PBA at 1000 ppm to the stock plant from which the cuttings are taken greatly retards rooting of those cuttings. The application of cytokinin to the apical end of

the cuttings at the time of propagation does not interfere with rooting, however, and may enhance it. The growth regulators N_6BA, PBA, and ethephon are useful in promoting lateral bud development on cuttings of Dracaena marginata. In this respect ethephon is superior to the other chemicals. The most effective concentration for both N_6BA and PBA was 500 ppm, and for ethephon 1000 ppm.

A recommended treatment for propagating stem cuttings is to apply PBA at 500 ppm to the apical end of the cuttings, and IBA at 3000 ppm to the basal end of the cutting at the time of propagation.

Disease in the cuttings may be reduced by curing the cuttings in an open greenhouse with at least 50% shading, and exposed to temperatures between 15.5 and 31°C, with relative humidity around 70%. Dipping these cuttings in a solution of Captan after curing is also beneficial. Hardwood cuttings appear to be the least affected by Erwinia carotovora and Fusarium moniliforme, and 30 cm cuttings are less affected than ten cm cuttings.

A recommended treatment is to cure the cuttings in a roofed shelter for at least four days, followed by a post-curing dip in Captan at 2.4 grams per liter of water.

APPENDIX

APPENDIX

Suggestions for Future Research

The results of this research present some useful information about various aspects of growth, stock plant management, and propagation of Dracaena marginata. Further research however is needed in these areas of concern.

Because environmental factors such as light intensity, available moisture, and temperature, affect the growth of stock plants, a thorough study on the effects of these different regimes on the growth of Dracaena marginata would provide valuable information necessary for developing efficient stock plant culture techniques. It would be especially valuable to find the optimum levels of the different mineral elements for growth and lateral bud development. It would also be beneficial to undertake further stock plant management studies with regards to the effects of cutting techniques on the return and yield of lateral shoots from these stock plants.

It would be of considerable interest to determine whether new shoots developing on cytokinin treated cut-back stems would produce difficult to root cuttings due to the translocation of the cytokinin. It would be interesting to determine the amount of time required for this inhibition to no longer be significant.

It would be worthwhile to investigate the effects of ethephon at 1000 ppm and PBA at 500 ppm on root development of cuttings, as these materials are very effective in promoting shoot development, and may not retard rooting if applied only to the upper end of the cuttings at the time of propagation.

Allowing several leaves to remain on a cut-back stem of a stock plant below the cut surface, may effect the initiation and regrowth of lateral shoots from these stems. This would be worth investigating.

Treating an entire cutting with cytokinins might stimulate the initiation of many more buds on the stem than merely treating the uppermost 7 cm. These developing buds could be excised, and it may be possible to root them under aseptic conditions.

Rooting cofactors could be studied to find what other materials besides auxins are important in rooting Dracaena marginata cuttings. If these compounds were applied to stem cuttings they may be able to root as readily as terminal cuttings.

It was noticed during these experiments that mist caused a chlorosis and stunting of the leaves of shoots developing on these cuttings, possibly because of a leaching action of the mist. If nutrients were added to the mist water, this may replenish the lost nutrients from the leaves due to leaching.

The disease control experiments undertaken in this research are far from conclusive. The goal of these experiments was to provide a very sure way of preventing the loss of cuttings due to disease. Experiments regarding the use of controlled temperature and humidity chambers are necessary, particularly with regards to preventing the development of fungi on the cuttings under these conditions. Methods of surface sterilizing the cuttings should be improved. It is possible that certain pathogens could live inside the cutting tissue and are not destroyed by chemical sterilization treatments. If this possibility is a fact it would be valuable to find a means of controlling these

pathogens. The formation of periderm on the cut surface of cuttings may be affected by such factors as the temperature, relative humidity and the age or stage of development of the cuttings. Experiments designed to measure periderm formation on cuttings under a number of different conditions would provide information on this subject.

BIBLIOGRAPHY

1. Beck, G. R., and K. C. Sink, Jr. 1974. Rooting stimulation of poinsettia stem cuttings by growth regulators. HortScience 9:144-146.

2. Blomme, R., and J. V. Hulle. 1971. Chamaecyparis pisifera. B.V.O. Medelingen no. 60. Hort Abstracts 42:8097.

3. Boe, A. A., R. B. Stewart, and T. J. Banko. 1972. Effects of growth regulators on root and shoot development of sedum leaf cuttings. HortScience 7:404-405.

4. Boswell, S. B., and W. B. Storey. 1974. Cytokinin-induced axillary bud sprouting in Macadamia. HortScience 9:115-116.

5. Carpenter, W. J., and G. R. Beck. 1972. Growth regulator induced branching of poinsettia stock plants. HortScience 7:405-406.

6. Carpenter, W. J., G. R. Beck, and G. A. Anderson. 1973. High intensity supplementary lighting during rooting of herbaceous cuttings. HortScience 8:338-340.

7. _____. 1974. High intensity supplementary lighting during rooting of herbaceous cuttings. Michigan Florist 517:10-13. Hort Abstracts 45:1802.

8. Carpenter, W. J., R. C. Rodriguez, and W. H. Carlson. 1971. Growth regulator induced branching on non-pinched poinsettias. HortScience 6:457-458.

9. Chadwick, L. C., and D. C. Kiplinger. 1938. The effect of synthetic growth substances on the rooting and subsequent growth of ornamental plants. Proc. Amer. Soc. Hort. Sci. 36:808-816.

10. Fritz, T. A., and T. S. Davis. 1971. Effect of indolebutyric acid and succinic acid-2,2-dimethylhydrazide on adventitious root formation of woody cuttings. HortScience 6:18-19.

11. Galston, A. W., and P. J. Davies. 1970. Control Mechanisms in Plant Development. Prentice-Hall, Inc., New Jersey. 175 p.

12. Gouvillon, G. A., and F. A. Pokorny. 1968. Photoperiod, indolebutyric acid, and type of cutting wood as factors in the rooting of Rabbiteye Blueberry (Vaccinium ashei Reode), cv. Woodward. HortScience 3:74-75.

13. Hartmann, R. T., and D. E. Kester. 1968. Anatomical and physiological basis of propagation by cuttings. p. 222-274. In R. T. Hartmann, Plant Propagation, Principles and Practices. Prentice-Hall, Inc., New Jersey.

14. Hess, C. E., and W. E. Snyder. 1955. A physiological comparison of the use of mist with other propagation procedures used in rooting cuttings. Rpt. 14th Int. Hort. Cong. p. 1133-1139.

15. Johnson, H. B. 1966. Bacterial soft rot in Bell Peppers: cause and commercial control. Marketing Res. Rep. USDA 738:1-6. Hort Abstracts 37:3072.

16. Kapustin, M. N. 1967. Bakterial'nye Mokrye gnili Kartofela. (Bacterial Wet Rots of Potato). Zasch. Rost. Mosk. 12:30-31. Review of Applied Mycology 46:3552.

17. Kender, W. J., and S. Carpenter. 1972. Stimulation of lateral bud growth of apple trees by 6-benzylamino purine. HortScience 3:68-69.

18. Kunisaki, J. T., and Y. Sagawa. 1971. Intermittent mist to root anthurium cuttings. Hawaii Farm Science 20:4-5.

19. Long, W. G., D. V. Sweet, and H. B. Tukey. 1956. The loss of nutrients from plant foliage by leaching, as indicated by radio-isotopes. Science 123:1039-1040.

20. Langhans, R. W. 1955. Mist for growing plants. Farm Res. (Cornell Univ.) 21:3. Cited from Hartmann and Kester (13).

21. Li, J. C. R. 1957. Introduction to Statistical Inference. By author. Dist. by Edwards Bros., Inc., Ann Arbor, Mich. 533 p.

22. Marlatt, R. B. 1972. Growth characteristics of Ficus elastica Roxb. HortScience 7:416.

23. McGuire, J. J. 1969. Uptake to IAA-2-14C by cuttings of Ilex crenata 'Convexa'. J. Amer. Soc. Hort. Sci. 94:44-45.

24. McGuire, J. J., S. A. Luke, and V. G. Shutak. 1968. Effect of foliar application of 3-indolebutyric acid on rooting of cuttings of ornamental plants. Proc. Amer. Soc. Hort. Sci. 93:699-704.

25. Neal, M. C. 1965. Liliaceae. p. 204-206. In M. C. Neal, In Gardens of Hawaii. Bernice Pauahi Bishop Museum, Honolulu.

26. Overbeek, J. v. 1938-1939. Auxin distribution in seedlings, and its bearing on the problem of bud inhibition. Bot. Gaz. 100:133-166.

27. Parups, E. V. 1971. Use of 6-benzylamino purine and adenine to induce bottom breaks in greenhouse roses. HortScience 6:457-458.

28. Phillips, I. D. J. 1971. Introduction to the Biochemistry and Physiology of Plant Growth Hormones. McGraw-Hill, New York. 173 p.

29. Sachs, T., and K. V. Thimann. 1964. Release of lateral buds from apical dominance. Nature 201:939-940.

30. _____. 1967. The role of auxins and cytokinins in the release of buds from dominance. Amer. Jour. Bot. 54:136-144.

31. Shanks, J. B. 1969. Some effects and potential uses of ethrel on ornamental crops. HortScience 4:56-58.

32. Snedecor, G. W., and W. G. Cochran. 1967. Statistical Methods. The Iowa State Univ. Press, Ames, Iowa. 575 p.

33. Stevens, G. A., Jr., and R. A. Criley. 1974. The effect of three growth regulators on shoot initiation and development in Cordyline terminalis. The Plant Propagator 20:20-23.

34. Tillburg, E. 1974. Levels of indol-3yl-acetic acid and acid inhibitors in green and etiolated bean seedlings (P. vulgaris). Physiol. Plant. 31:106-111.

35. Tukey, H. B., Jr., H. B. Tukey, and S. H. Wittwer. 1958. Loss of nutrients by foliar leaching as determined by radioisotopes. Proc. Amer. Soc. Hort. Sci. 71:496-506.

36. USDA. 1953. The disease bacteria cause. p. 817-821. In USDA Plant Diseases, The Yearbook of Agriculture. U. S. Gov. Printing Office, Washington, D. C.

37. Walker, J. C. 1957. Plant Pathology. McGraw-Hill, New York. 692 p.

38. Weaver, R. J. 1972. Plant Growth Substances in Agriculture. Freeman and Co., San Francisco. 561 p.

39. Wehlburg, C., and A. P. Martinez. 1967. Leaf spot of Dracaena marginata Lam., caused by Fusarium moniliforme Sheld. and its control. Proc. Flor. State Hort. Soc. Vol. 80.

40. Went, F. W. 1938. Specific factors other than auxin affecting growth and root formation. Plant Physiol. 13:55-80.

41. Went, F. W., and K. V. Thimann. 1937. Phytohormones. The Macmillan Co., New York. Cited from Hartmann and Kester (13).

42. Wickson, M., and K. V. Thimann. 1956. The antagonism between kinetin and indoleacetic acid in lateral bud development. Plant Physiol. 31 supp. p. XXVIII.

43. _____. 1958. The antagonism of auxin and kinetin in apical dominance. Physiol. Plant. 11:62-74.

44. Williams, M. W., and H. D. Billingsley. 1970. Increasing the number and crotch angles of primary branches of apple trees with cytokinins and gibberellic acid. J. Amer. Soc. Hort. Sci. 95: 649-651.

45. Williams, M. W., and E. A. Stohly. 1968. Effect of cytokinins on apple shoot development from axillary buds. HortScience 3: 68-69.

46. Wott, J. A., and H. B. Tukey, Jr. 1966. Plant propagation with nutrient mist. Farm Res. (NY Agr. Exp. Sta.) 32:6-7. Cited from Hartmann and Kester (13).